Procedures and Guidelines

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Title: Mechanical Design and Development Guidelines

1. PURPOSE

This PG establishes guidelines for Product Design Team (PDT) members providing mechanical design and development support to GSFC products covered by the scope of the GSFC Quality System.

2. REFERENCES

GPG 1310.1, Customer Commitments and Review
GPG 1710.1, Corrective and Preventive Action
GPG 5330.1, Product Processing, Inspection, and Test
GPG 5340.2, Control of Non-conforming Product
GPG 8700.1, Design Planning and Interface Management
GPG 8700.2, Design Development
GPG 8700.3, Design Validation
GPG 8700.4, Technical Review Program
GPG 8730.3, The GSFC Quality Manual
500-PG-1310.1.1, External Customer Agreements
500-PG-8700.2.3, Issue and Management of Engineering Drawing Numbers
500-PG-8700.2.5, Engineering Drawing Standards Manual
548-PG-8072.1.2, Fabrication Management Process
5405-048-98, Mechanical Systems Center Safety Manual

3. SCOPE

This PG establishes guidelines for Product Design Team (PDT) members providing mechanical design and development support to GSFC products covered by the scope of the GSFC Quality System.

4. DEFINITIONS

a. Product Design Lead (PDL) - The PDL is the manager or leader with overall responsibility for managing the design activity, managing the technical and organizational interfaces identified during design planning, and where required, forming and leading the Product Design Team (PDT). The term PDL may refer to flight project managers, mission managers, instrument managers, subsystem technical managers, integrated product development team leaders, lead engineers, or others who have

the responsibility for managing a design activity. In the context of this document, PDL refers to a "lead engineer."

b. Customer - Any organization or person receiving mechanical design and development support from the AETD.

c. Design Plan – The documentation created as a result of executing GPG 8700.1, Design Planning and Interface Management. This documentation consists of schedules and budgets, a work breakdown structure, a validation plan and other information. It may be gathered together as a single document, consist of multiple documents, or be a portion of a more comprehensive document, such as a Project Plan, Implementation Plan, or equivalent.

5. AUTHORITIES AND RESPONSIBILITIES

The PDL, hereafter referred to as the lead engineer, is responsible for the quality and timely completion of the mechanical design and development activities as specified in the Customer Agreement and/or Statement of Work (SOW) (see GPG 1310.1, Customer Commitments and Review; and 500-PG-1310.1.1, External Customer Agreements). This includes providing the design output (documentation including engineering drawings, test plans, procedures, and reports), budgets, schedules, and review support to the customer (typically a project or instrument manager). It is the responsibility of the lead engineer, in partnership with the customer, to determine and document in a design plan (per GPG 8700.1, Design Planning and Interface Management) which specific steps of the typical mechanical design and development process (as described herein) will be executed.

6. CANCELLATION

500-PG-8700.2.4, Mechanical Design and Development Guidelines

7. RECORDS

Although no unique quality records are generated as a result of this PG, certain important quality records are listed in the table below with reference to the corresponding GPG.

Quality Record Title	Record Custodian	Retention
Design Planning Documentation and/or Implementation Plan Reference: GPG 8700.1	Lead Engineer, then Project Office (at completion of development activity)	NASA Records Retention Schedule (NRRS) 1/22A. Permanent. Retire to a Federal Records Center (FRC) when 5 years old. Transfer to NARA when 10 years old.
Work Order Authorization (WOA) Reference: GPG 5330.1	Lead Engineer, then Project Office (at completion of development activity)	NRRS 8/5A2. Project Test, Engineering, and Evaluation Files. Records may be retired to an FRC when 2 years old. Destroy when 15 years old.

Design Verification Test Reports and/or Summaries Reference: GPG 8700.3	Lead Engineer, then Project Office (at completion of development activity)	NRRS 8/5A2.
System/Peer Review Requests for Action and Responses, and Summaries Reference: GPG 8700.4	System Review Office/Project Office	NRRS 7/5B1. Permanent. Documents may be retired to FRC 1 year after publication. Transfer to NARA when 25 years old.

8. IMPLEMENTATION

The following procedure describes a typical process for providing mechanical design and development support to a customer. Again, for the purposes of this document, customer would typically refer to a project or instrument manager. The actual design and development process is by nature iterative and must maintain some degree of flexibility.

8.1 Compilation of Design Inputs

The lead engineer compiles and evaluates the Design Inputs which may include one or more of the following:

- Statement of Work
- Customer imposed requirements
- Interface Control Drawings (ICD)
- Applicable specifications, standards, and statutory/regulatory requirements
- AETD imposed requirements

8.2 Initial Planning

8.2.1 The lead engineer develops the design planning documentation which contains a high level description of the mechanical hardware to be developed, key support personnel, a budget, and a schedule for review and approval by the customer. The plan should include adequate contingencies for completion of the design and development activity within the resources negotiated in the Customer Agreement and/or SOW (see GPG 1310.1, Customer Commitments and Review and/or 500-PG-1310.1, External Customer Agreements). A project or instrument manager may request this design plan information be documented in a formal Implementation Plan for the mechanical subsystem. Other approaches may be to have the design planning documentation combined with other discipline inputs and consolidated into a Project Plan, or the design planning documentation may be a part of several individual project documents. Regardless of the approach, the design planning documentation is a quality record and shall be maintained per the applicable configuration management plan for this design and development activity.

8.2.2 The lead engineer ensures that the PDT is composed of individuals, civil servants and/or contractors as necessary, with the required discipline skills.

8.3 Requirements Definition

The lead engineer supports the generation of a requirements document from the design inputs. It may be necessary for the PDT to perform various analyses in order to derive lower level design requirements from the top level design inputs. These top level and derived requirements shall be documented, reviewed for adequacy and consistency with relevant NASA and GSFC standards, and signed off by the lead engineer and the customer. The requirements document shall be maintained per the applicable configuration management plan.

8.4 Design Practice

The design effort should be conducted according to GPG 8700.2, Design Development, and according to the following good design practices, as appropriate:

8.4.1 Multiple design concepts should be identified, and the best selected by a trade study process. The best design concept is that which fully meets all of the design requirements and considers cost, technical complexity, schedule risk, technology infusion, design heritage, and other factors as appropriate. It may be necessary to prototype one or more of the design options and to conduct various performance and/or environmental tests before the optimum design path is chosen. In any case, the customer shall be a key participant in this critical selection process. In addition, the results of the trade study process are typically "peer reviewed." (See GPG 8700.4, Technical Review Program)

8.4.2 Detailed designs should be as simple as possible, making maximum use of standardization, repeated elements, known processes, and readily available parts and materials.

8.4.3 Designs should be robust, insensitive to fabrication tolerances, and consider ease of assembly. Tolerances specified on drawings should be achievable and only what is needed for proper operation/function. Excessively tight tolerances result in higher costs to manufacture, potentially more rejected parts, and usually longer lead times before delivery.

8.4.4 All appropriate functional discipline personnel (e.g., manufacturing, testing, instrument assembly) having interfaces which should be considered should be a part of the PDT, or, as a minimum, be consulted to review the design and make suggestions to improve manufacturability and/or reduce the manufacturing costs. The lead engineer shall decide whether to accept or reject these recommendations.

8.4.5 Fabrication drawings of flight hardware and ground support equipment hardware that interfaces with flight hardware shall be produced in accordance with 500-PG-8700.2.5, Engineering Drawing Standards Manual. Some or all of these drawing practices may also be applicable to pre-flight and pre-operational hardware (such as engineering test units, breadboards, and proof-of-concept hardware), but are not required. Applicability shall be determined by the lead engineer. Fabrication drawings shall be complete and unambiguous, containing all the necessary information to produce the desired part. Instructions for obtaining official GSFC Drawing Numbers can be found in 500-PG-8700.2.3, Issue and Management of Engineering Drawing Numbers.

8.4.6 The lead engineer is responsible for assuring that all fabrication drawings of flight hardware and ground support equipment hardware that interfaces with flight hardware are checked for accuracy and completeness. For multiple part assemblies, assembly drawings, detailed layout drawings, or some other means to convey how the piece parts fit together should be provided so that tolerance studies can be conducted to assure proper fit.

8.4.7 The following short checklists of Mechanical Design Considerations and commonly used Mechanical Design References are provided as an aid in implementing the design:

8.4.7.1 Mechanical Design Considerations:

- Materials selection (space flight qualified, ferrous/non-ferrous, composite, ceramic, etc.)
- Environmental effects (static and dynamic loads, temperature, humidity, radiation, etc.)
- Analyses required (structural, thermal, optical, or various combinations of these analyses, torque margin, fracture, fatigue, vibroacoustic, transportation, venting, pressure, etc.,)
- Ground support equipment (GSE) and logistics (handling, shipping, maintenance, storage)
- Ease of manufacture and assembly
- Testability
- Contamination control
- Fracture control

8.4.7.2 Mechanical Design References:

- ANSI Y14-5M, Dimensioning and Tolerancing for Drawings
- GEVS-SE, General Environmental Verification Specification for STS & ELV Payloads, Subsystems and Components
- Mechanical Systems Center Safety Manual, No. 5405-048-98
- MIL-HDBK-5 (Metals)
- MIL-HDBK-17 (Composites)
- NASA-STD-5000 and -7000 series
- NSS/GO-1740.9 Safety Standard for Lifting Devices and Equipment
- S-313-100, Goddard Space Flight Center Fastener Integrity Requirements
- 127-1 Eastern/Western Range Safety Requirements
- 500-PG-8700.2.5, Engineering Drawing Standards Manual
- 731-0005-83 Fracture Control Plan for Payloads Using STS

8.5 Design Changes

Design changes, as required by customer request, process improvement, errors in the original design, improper component selection, drawing error, product non-conformance, etc., shall be documented, approved, and implemented per the relevant configuration management plan.

8.6 Design Reviews

At appropriate stages throughout the mechanical design and development process, reviews shall be scheduled and conducted.

8.6.1 Internal reviews are held during the design process and are truly at the grass roots level. Participants of these informal reviews are usually members of the PDT and other mechanical engineers/technicians. Though not required, informal documentation and tracking of action items sometimes occurs at the discretion of the lead engineer.

8.6.2 Peer Reviews (See GPG 8700.4, Technical Review Program) are more formal reviews that evaluate a design's technical status using a team of appropriate specialists independent from the PDT. They are conducted as specified in the Peer Review Plan. Emphasis should be placed on selecting a well-rounded review team consisting of personnel cognizant of and experienced with the subject matter of the review. These reviews are conducted to ensure that the mechanical design fully meets the design requirements. It is the responsibility of the lead engineer and/or PDT to respond to all Requests for Action (RFA's) generated at the reviews. Peer Reviews can be scheduled at any time during the design and development process. Some typical reasons for scheduling a Peer Review could be any one or more of the following:

- Required per the Peer Review Plan
- Review a new design
- Review results of trade study
- Review modifications to an existing design or to existing design requirements
- Preparation for a System Review
- Preparation for a complex functional or environmental test
- Preparation for a complex shipment of hardware

8.6.3 System Reviews (See GPG 8700.4, Technical Review Program) are formal, technical reviews that systematically evaluate a Project's technical status. They are conducted as specified in the project's Systems Review Plan. The System Review Team consists of a chairperson from the System Review Office and a team of specialists independent from the PDT. The status of the mechanical design and development is presented at these reviews by the mechanical lead engineer/PDT. Other lead engineers/PDTs present the status of their respective subsystems at these reviews. These reviews are conducted to ensure that the system design fully meets the design requirements. Again, it is the responsibility of the lead engineer and/or PDT to respond to all Requests for Action (RFA's) generated at the reviews for their respective subsystem. Reviews typically conducted include a Systems Concept Review, Preliminary Design Review, Critical Design Review, Pre-Environmental Test Review, and a Pre-Ship Review.

8.7 Design Verification

During the engineering design and development process, design verification will be conducted as required to ensure that the design meets all of the customer's requirements. Verification will be conducted by a combination of analysis, review, and test.

8.7.1 The following analyses will be performed and documented as appropriate:

- Structural Analysis
- Thermal Analysis

- Dynamic Simulation
- Various other methods of calculation/analysis, such as combined structural, thermal and optical analyses, stray light analyses, etc.
- Review and comparison to similar systems/designs

8.7.2 Peer and Systems reviews will be conducted as described in Section 8.6 of this procedure to verify that the design and test documentation meets all customer requirements.

8.7.3 Development and testing of proof-of-concept designs, engineering or qualification test units, and life test units may also be conducted as part of the design verification.

8.7.4 The Work Order Authorization (WOA) shall be utilized (per GPG 5330.1, Product Processing, Inspection, and Test) to plan and document the processing of a product as it progresses from the initial stages of manufacture through integration, inspection, and test events, including all functional and environmental tests, required for design verification.

8.8 Design Validation

The lead engineer/PDT shall validate the product in accordance with GPG 8700.3, Design Validation. Validation includes manufacture, integration to larger systems/assemblies, as well as environmental and functional tests. Note that due to the iterative nature of the design process, intermediate validation is frequently required.

8.8.1 The lead engineer shall determine the most appropriate and efficient method for fabrication of the hardware. Options include the Fabrication Engineering Branch, which provides a full complement of planning, contracting, and monitoring services (See 548-PG-8072.1.2, Fabrication Management Process, for more detailed information), task order contracts, or any other contracting medium that accesses a viable fabrication resource. Please note that fabrication tasks processed through the Fabrication Engineering Branch require a Work Request (GSFC 8-11) to initiate the fabrication effort and do not require a WOA.

8.8.2 All flight hardware and GSE that interfaces with flight hardware shall have critical dimensions, as a minimum, inspected. The lead engineer is responsible for identifying the critical dimensions and for the disposition of any discrepancies. Discrepant parts may be dispositioned as “rework, repair, use-as-is, reclassify, return to vendor, or scrap.” See GPG 5340.2, Control of Nonconforming Product, for more detailed information.

8.8.3 Assembly and integration of flight hardware shall be performed in accordance with an assembly drawing and/or plan. Integration, inspection and test events shall be documented via the Work Order Authorization process defined in GPG 5330.1, Product Processing, Inspection and Test. All assembly and integration activities shall be performed with the appropriate safety considerations addressed for personnel and/or hardware, and under the appropriate environmental conditions. Some items for consideration are:

- Cleanliness requirements
- Temperature/Humidity requirements

- Crane access
- Adequate space
- Unique power and/or grounding requirements
- Alignment operations requiring specialized GSE
- Special Tooling/Fixturing
- Safety considerations (See Mechanical Systems Center Safety Manual, Document No. 5405-048-98.)

8.8.4 Validation testing shall be conducted using approved (formally released) validation test plans and procedures. The following extensive list of validation tests, the majority of which have significant mechanical design implications, shall be conducted as appropriate:

- Interface testing (mechanical and electrical)
- Functional testing
- Life testing
- Mass Properties testing
- Spin Balance
- Strength testing (static pull, sine burst, or centrifuge testing)
- Vibration testing (random and/or sine sweep)
- Shock testing
- Acoustics testing
- Modal testing
- Thermal Vacuum testing
- Thermal Balance testing
- EMI/EMC testing
- Magnetic testing

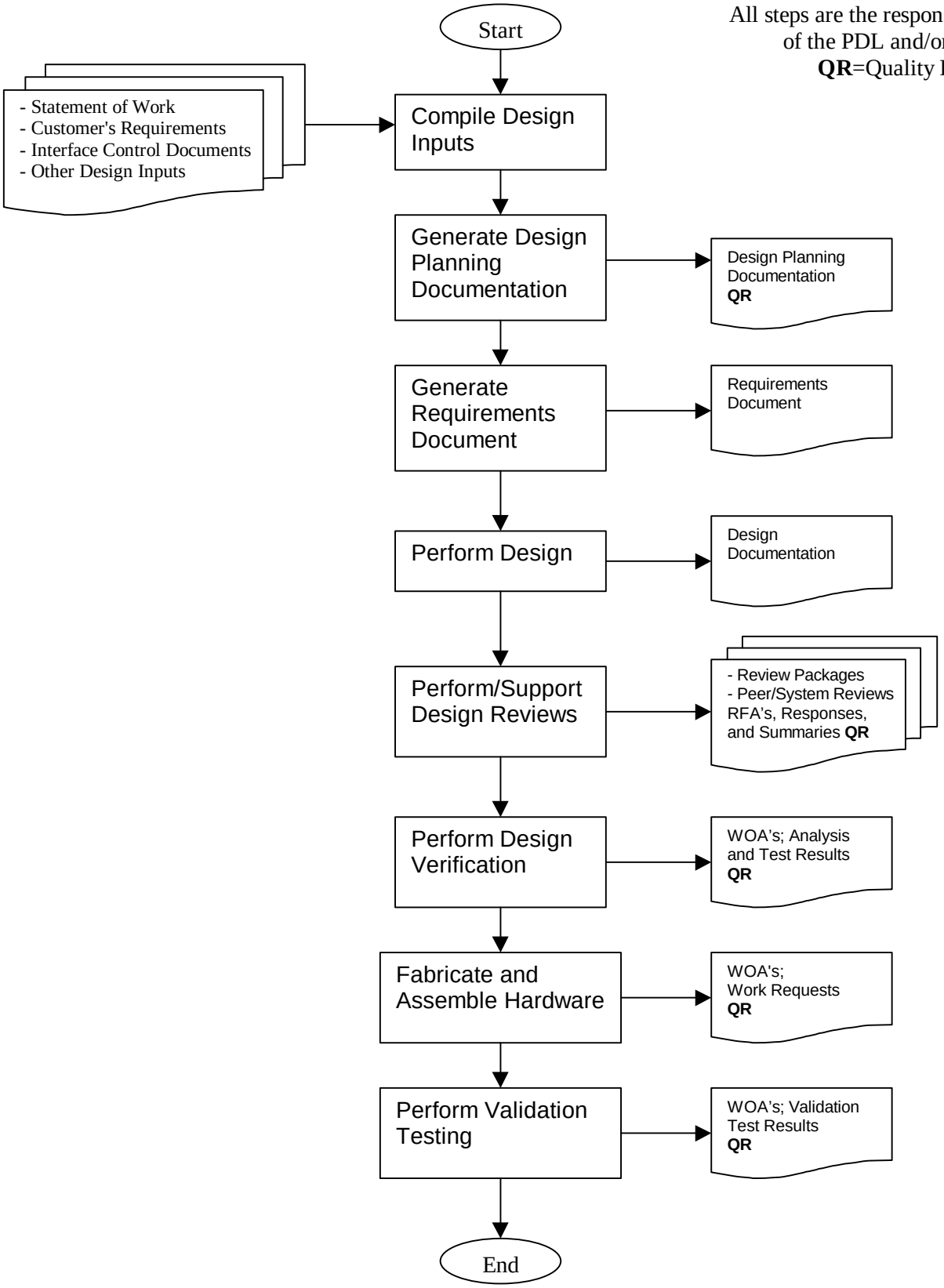
8.8.5 All tests shall be analyzed and evaluated to ensure that all customer requirements have been validated. Anomalies found during the validation process shall be documented and resolved per GPG 5340.2, Control of Non-conforming Product, and GPG 1710.1, Corrective and Preventive Action.

8.9 Communicate Design Output

The lead engineer/PDT shall assure that both the design output (e.g., engineering drawings, test plans, procedures, reports, review documentation) and the design progress (technical, budget, schedule) are communicated to the appropriate configuration management system per GPG 8700.2, Design Development and to the customer upon request.

Flowchart

All steps are the responsibility of the PDL and/or PDT.
QR=Quality Record



CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
Baseline	01/14/99	Initial Release
A	06/10/99	Modified format to conform with GPG 1410.1A. Corrected incorrect document number references (500-PG-1310.1.1). Listed references in numerical order. Clarified quality records requirements in text and flowchart. Clarified WOA usage requirements for verification and validation. Introduced the Work Request form used in the Fabrication Management Process. Clarified drawing standards requirements for engineering test units versus flight units.
B	08/17/1999	Added Design Plan definition from GPG 8700.1. In 8.2.1, provided several approaches for documenting design plan information. Added GPG references to Quality Record Title. Under Implementation, added clarifying words for "customer" as used in the context of this document.